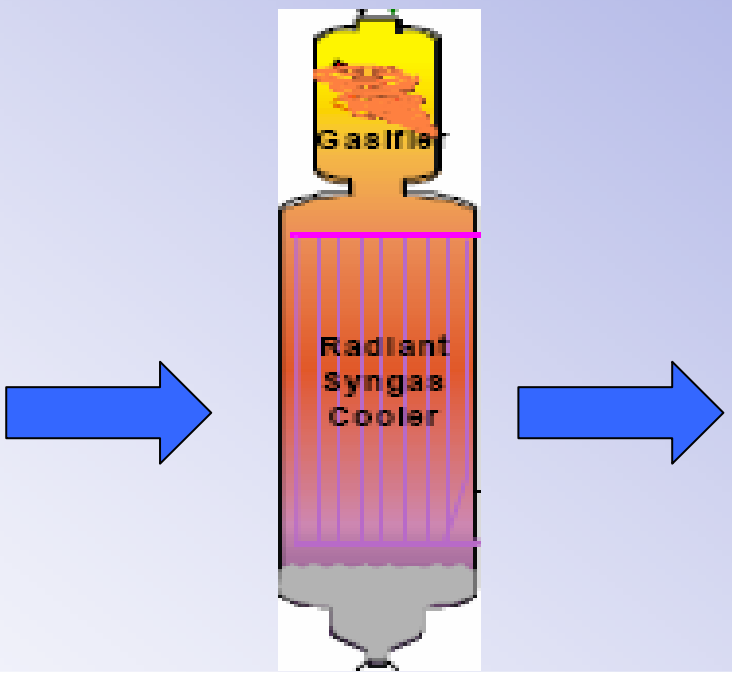
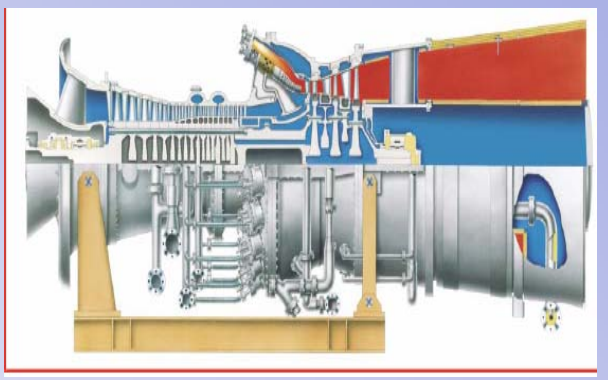
Real-World Experience with IGCC – Lessons Learned in Design, Permitting, Operations and Maintenance





Steve Jenkins
URS Corporation
August 17, 2005

Background

- Born in California!
- 30 years in Power Industry
- 25 years with Tampa Electric Company
- Former Deputy Project Manager, Polk Power Station IGCC Project

Thanks!

- Mark Hornick – General Manager – Polk Power Station
- John McDaniel – Sr. Engineering Fellow – Polk Power Station
  - Worked on Cool Water IGCC project

Tampa Electric Company

- Mid-sized utility in west-central Florida
- About 4,400 MW total generating capacity
- 600,000 customers
- Decision to use coal in 1959 when the company could not get long-term contracts for oil from Middle East
- Set up coal transportation system
  - Mississippi River barges
  - Terminal on the Mississippi delta
  - Ocean-going ships to deliver coal to Tampa and back-haul fertilizer from central Florida

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Coal Delivery System

Tampa Electric Company

- Three power plants
  - Hookers Point: small oil-fired units installed after WWII
  - Gannon Station: coal-fired units (1958-1968)
  - Big Bend Station: coal-fired units (1970-1985)
- Commitment to coal – generation was ~97% coal-fired
- Commitment to environmental performance – first FGD system in U.S. designed to produce commercial grade gypsum for wallboard

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Why IGCC?

- Early 1990s was start of transition of power industry
- Company recognized need for new base-load generation by the mid-1990s
- Formed 17-member citizen site selection committee to choose site and technology
- Competition for development of new base-load units by IPPs, but through use of quick-build combined cycle units and natural gas
- How to preserve commitment to low-cost coal?

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Why IGCC?

- DOE Clean Coal Technology Program
- Offered co-funding for new coal-based technology
- Opportunity to build new generation, continue commitment to low-cost coal, and demonstrate state-of-the-art technology
- Tampa Electric submitted application and was selected

Polk Power Station

- Site Selection Committee chose site in central Florida, previously mined for phosphate
- “Moonscape” reclaimed into power plant site and 800-acre cooling reservoir

Original Site Plan

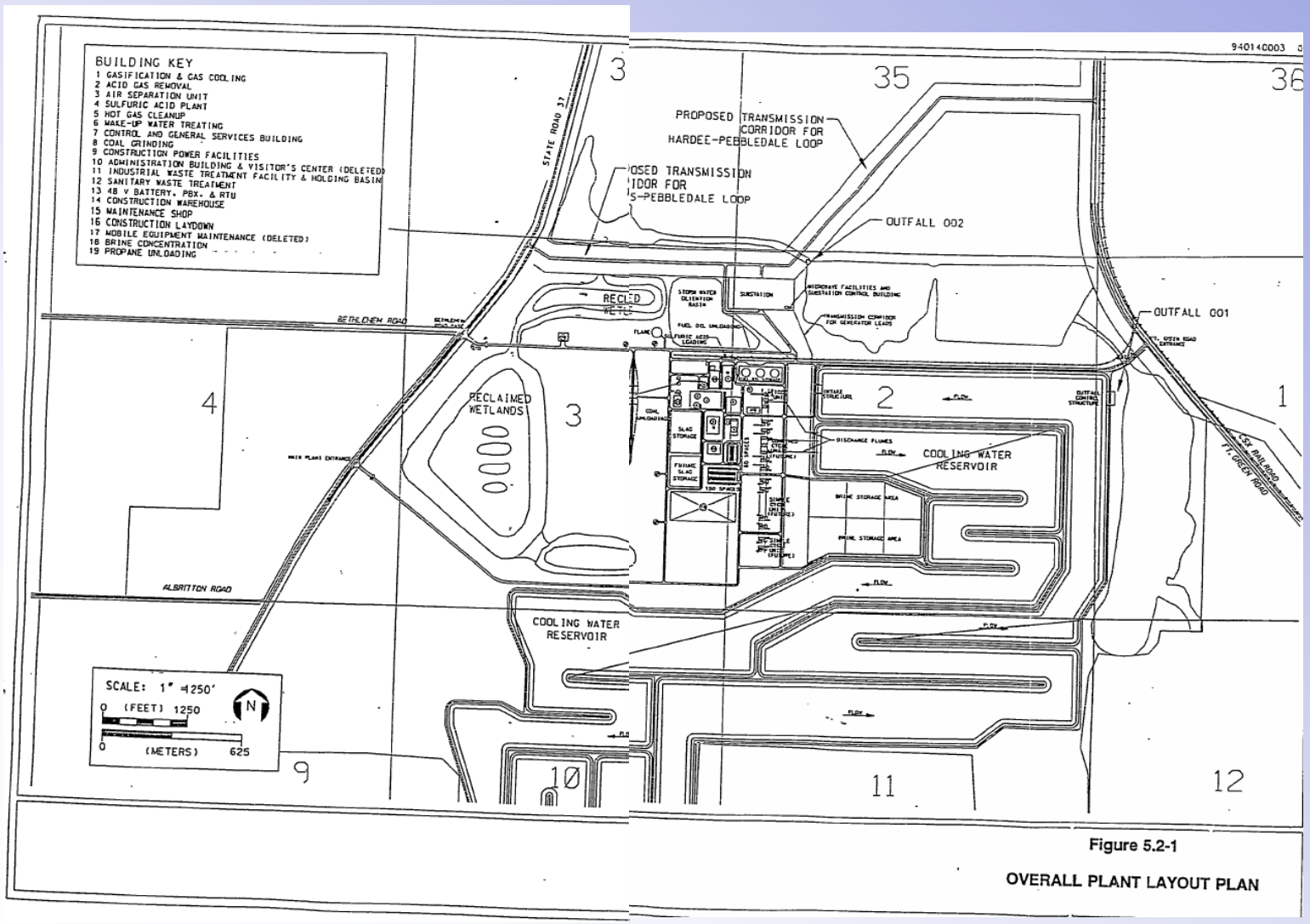
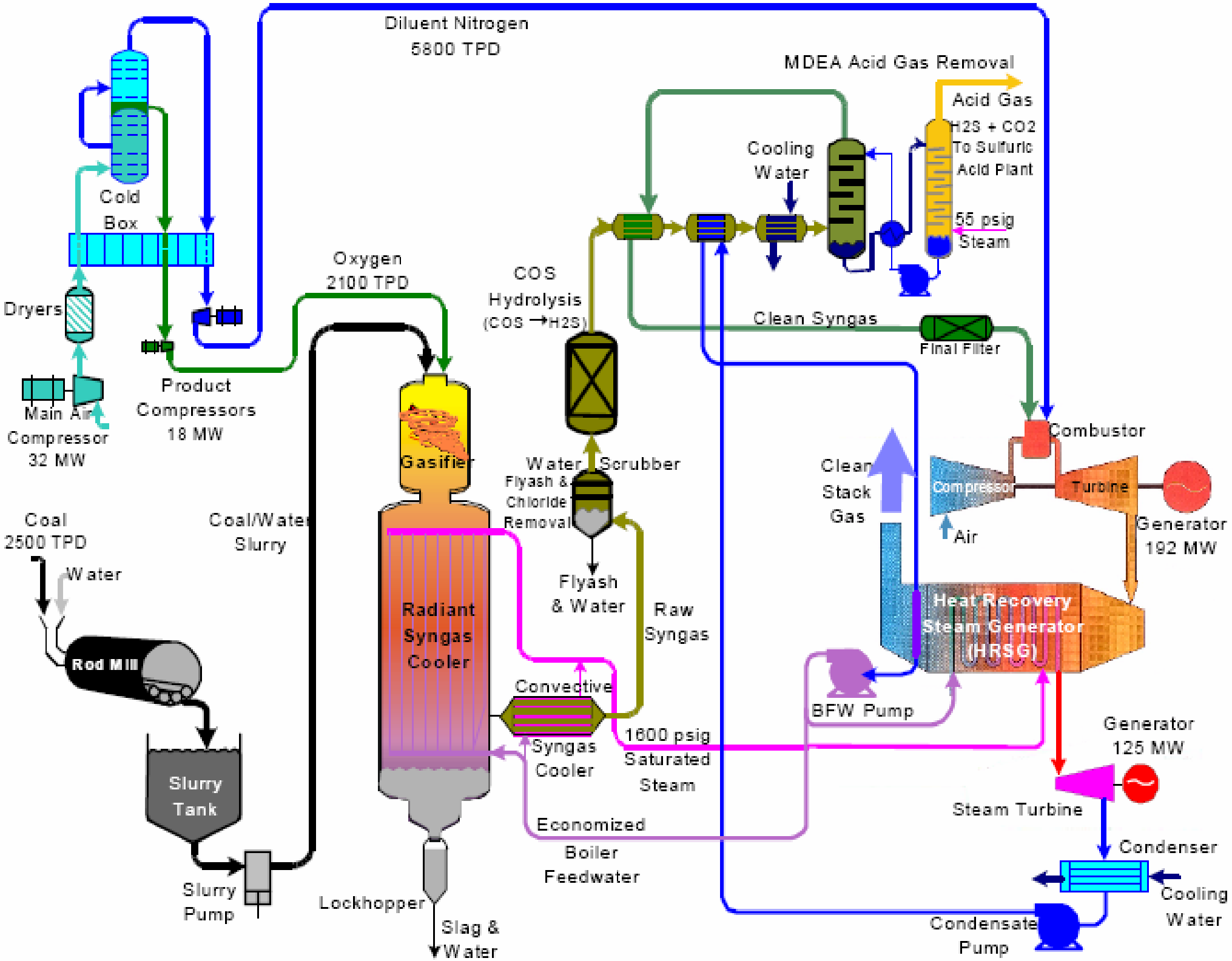
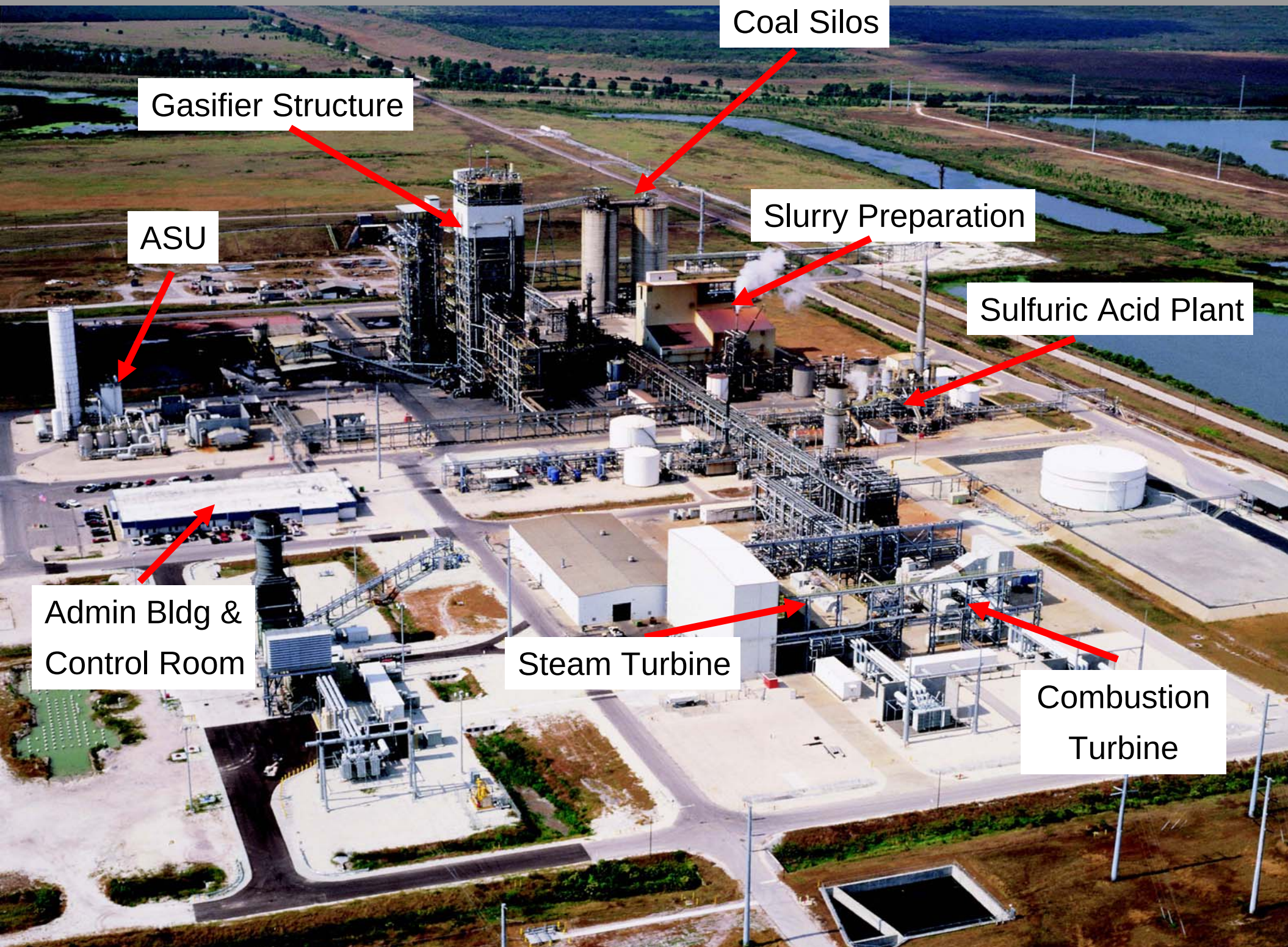


Figure 5.2-1

OVERALL PLANT LAYOUT PLAN

Polk Power Station


Diluent Nitrogen
5800 TPD
MDEA Acid Gas Removal
Acid Gas
H2S + CO2
To Sulfuric
Acid Plant
Cooling
Water
55 psig
Steam
Cold
Box
Oxygen
2100 TPD
COS
Hydrolysis
(COS → H2S)
Clean Syngas
Final Filter
Dryers
Product
Compressors
18 MW
Main Air
Compressor
32 MW
Gasifier
Water Scrubber
Flyash &
Chloride
Removal
Combustor
Clean
Stack
Gas
Compressor
Turbine
Air
Generator
192 MW
Coal
2500 TPD
Water
Coal/Water
Slurry
Radiant
Syngas
Cooler
Flyash
& Water
Raw
Syngas
Heat Recovery
Steam Generator
(HRSG)
Rod Mill
Convective
Syngas
Cooler
BFW Pump
Generator
125 MW
1600 psig
Saturated
Steam
Slurry
Tank
Steam Turbine
Economized
Boiler
Feedwater
Condenser
Slurry
Pump
Lockhopper
Slag &
Water
Cooling
Water
Condensate
Pump


Coal Silos
Gasifier Structure
ASU
Slurry Preparation
Sulfuric Acid Plant
Admin Bldg &
Control Room
Steam Turbine
Combustion
Turbine

Design Basis

- 250 MW (net)
- 2,500 tons/day of coal
  - Pittsburgh #8 coal for performance
  - Illinois # 6 coal for sulfur level
  - Coal is trucked 30 miles from Big Bend Station
- Removal and recovery of sulfur compounds as sulfuric acid
- Beneficial use of slag for use in making cement
- 800 acre cooling reservoir
- Zero process water discharge

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Permitting Issues

- Agencies had experience with coal-fired units, but mainly during 1970s and 80s
- Florida DEP and US EPA staff very familiar with gas-fired combined cycle units
- IGCC – is it gas or is it coal?
- Answer from Florida DEP - YES!
  - Permit the plant for least environmental impact
  - But no long-term history of IGCC permits
  - SO_2 emission limit same as best coal-fired unit
  - NOx emissions - go with diluent injection, but re-do NOx limit after DOE demonstration period and leave room for NOx controls (SCR)

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Start-up and Initial Operation

- IGCC Specialists
  - 5 teams of 10, all with journeyman level skills
  - Responsible for operation and maintenance
  - No front-line supervisor
- IGCC simulator used for training
- Total plant staff of 78
  - O&M, engineering, and administrative

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Start-up and Initial Operation

- Started up combined cycle power block on No. 2 oil in late spring 1996
- First syngas produced in July 1996
- First syngas to combustion turbine in September 1996
- Two-year DOE demonstration program

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Start-up

- Long start-up from “cold” conditions - not much different from coal-fired unit
- Air Separation Unit (cryogenic) takes several days to cool down - significant power consumption
- 30-36 hours to heat up gasifier and gasification train, using propane gas
  - Refractory must heat up slowly to prevent cracking
- 10-15 minutes after slurry introduced to get to full pressure
- Then 1-2 hours to heat up rest of gasification system and syngas piping to combustion turbine
- Syngas is flared instead of using it to make power

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Start-up and Year 1 of Operation

- Start-up challenges and problems not too different from coal-fired units or gas-fired combined cycle units
- Many little things contributed to lower than expected availability, but problems were not attributable to the basic IGCC technology
  - Piping erosion/corrosion
  - Ash pluggage in syngas coolers
- Power block problems with failed bolts in combustion turbine 3rd stage, and in combustors
  - Solved as Tampa Electric and GE became more experienced with syngas operation
- Many “nuisance” shutdowns

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Year 2

- Particulate matter damage to combustion turbine solved with syngas filter
- Start-up refractory replaced after only 1 year
- Sulfur removal not as high as expected on some sulfur compounds
  - Temporary switch to lower sulfur coals
  - Solved with system upgrade
- Plant staff learned how to do faster “hot” starts to reduce time and power consumption

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Syngas Cooler Pluggage

- Plugging in syngas coolers from ash deposition
  - Design of cooler entrance
  - Changes in ash characteristics of coals being tested

Year 3

- Transition - from working hard just to stay on line, to finding ways to improve performance
- Longest uninterrupted period of power generation from the combustion turbine: 52 days
  - 16 transfers between syngas and No. 2 oil
- Longest uninterrupted gasifier run: 37 days (improved burner)
- Gasifier refractory life: 451 days operation
  - Lasted over 2 years, with 73 gasifier startups on 10 different fuels or fuel blends
- Lowest generation cost in Tampa Electric fleet– first unit dispatched
- Continued ash pluggage problems
- Problems with unconverted carbon in slag

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Carbon in Slag

Contractor brought on site to screen carbon from slag

High carbon material trucked to Big Bend to mix with the coal

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Year 5

- Gasification plant operating much better
  - Many nuisance problems solved
  - Faster start-ups
  - Fewer corrosion and pluggage problems
  - Feedstock flexibility (petroleum coke)
- Failure of Air Separation Unit main air compressor – 1 month outage
- Air permit required re-look at NOx controls/limit
  - State agency wanted retrofit of SCR
  - SCR not proven on IGCC
  - GE refined system for syngas saturation to achieve 15 ppm
  - Continued discussions with FDEP and EPA

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Year 7

- Relative fuel prices
  - Pet coke = 1.0
  - Coal = 1.5
  - Natural gas = 4.3
  - No. 2 oil = 4.5
- Commitment to coal shows IGCC to be a smart choice

- NOx emission limit issue resolved by using syngas saturator, achieving 15 ppm
- Carbon in slag problem solved with new slag screen
- But problems with power block (not syngas related)
  - Both generators rewound
  - GE notifies Tampa Electric of combustion turbine rotor problem - replaced

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Year 8

- Best year ever!
- Much better performance overall
- 82% on-stream factor for gasification
- 96% availability for power block
- 99+% availability on-peak
- Using 55% pet coke/45% coal

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Year 9

- Overall IGCC performance greatly improved
- Faster start-ups with less use of parasitic power
- Using pet coke/Venezuelan coal blend
  - Low cost
  - Good ash characteristics
- But - combustion turbine air compressor failed in January – not syngas related
  - 100-day outage
  - Time for other improvements
  - Modification to take extraction air from combustion turbine, which will increase overall power output

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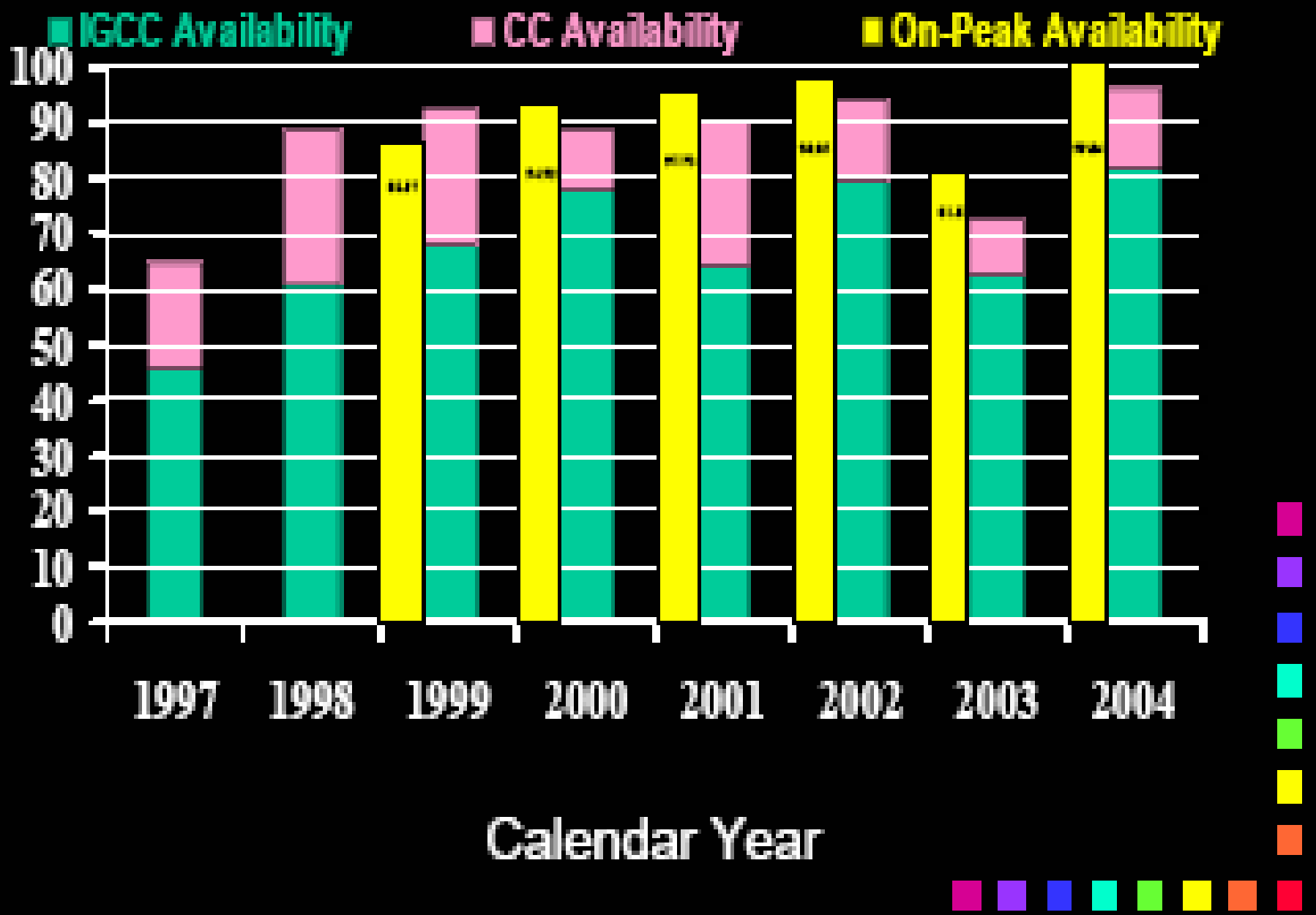
KEY AVAILABILITY STATISTICS



Average for coal-fired units is 87%

Environmental Performance

- SO_2 – ~98% removal
- NOx – syngas saturation achieves 15 ppm
- Reduced CO_2 emissions
- Ready market for sale of sulfuric acid
  - Sold to local phosphate industry and municipal water treatment plants
- Slag – beneficial use in making cement
- Low water consumption
- Zero process water discharge

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Polk Power Station History

- First 3 years were the toughest
- Many design and operation improvements
- High availability achieved - close to goal and getting better
- Continuous environmental performance enhancements, with sale of by-products
- Experience on 20 feedstocks provides opportunities for lowering cost of electricity

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Transfer of Lessons Learned

- Significant improvements in IGCC design, equipment layout, materials of construction, performance, heat rate, start-up procedures
- Experiences and improvements from Polk Power Station made available to EPRI CoalFleet program
- Next generation of IGCC plants will benefit from Polk Power Station's 9 years of experience
  - **Lower cost**
  - **Better performance**
  - **Higher availability**

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Tampa Electric Company
Polk Power Station